

525-18
102859
106

N88-10854

THERMAL TESTING BY INTERNAL IR HEATING OF THE FEP MODULE*

D. M. Nathanson, R. A. Efromson, E. I. Lee
M.I.T. Lincoln Laboratory

1028827

ABSTRACT

A spacecraft module, to be integrated with the FLTSATCOM spacecraft, was tested in a simulated orbit environment separate from the host spacecraft. Thermal-vacuum testing of the module was accomplished using internal IR heating rather than conventional external heat sources. For this configuration, the technique produced boundary conditions sufficiently similar to the average steady-state conditions expected for flight to enable verification of system performance and thermal design details.

INTRODUCTION

An EHF module and antenna system built at MIT Lincoln Laboratory will be integrated with each TRW FLTSATCOM Flight 7 and 8 spacecraft. The module will be attached to the aft end of the spacecraft and the antenna system will be included at the forward end. Together these are known as FLTSAT EHF Package (FEP). The FEP arrangement is shown in Fig. 1. The spacecraft will be in a near-geosynchronous orbit.

The EHF module forms a hexagon, 2.3 m (7.5 ft) across the flats, 1.2 m (4 ft) on a side and 36 cm (14 in.) tall. It consists of an aluminum frame, supporting 6 honeycomb panels, on the inside of which are mounted electronic components. The outsides of the panels are covered with second-surface mirrors and will have multilayer-insulation blankets to form the mirror apertures.

The EHF module is to be thermally isolated to minimize impact on FLTSATCOM. Low-conductivity attachments are to be used between the EHF module and spacecraft module. An insulation blanket will span the area between the sections. The thermal-insulation arrangement used at the aft end of previous FLTSATCOM spacecraft will be transferred to the aft end of the EHF module.

The system was to be thoroughly tested at Lincoln Laboratory prior to delivery. The EHF module was to be tested, separate from the host spacecraft, to boundary conditions similar to those expected for flight. The thermal performance of the electronic systems in vacuum could then be verified along with the performance of the exterior blankets and radiating surfaces. Geometric constraints of the thermal-vacuum facility precluded the use of solar simulation or external IR sources. The module could only be tested in a stationary position with minimal clearance between panel faces and the liquid-nitrogen-cooled shroud. The flight antenna system was tested separately but back-up antenna positioners

* This work was sponsored by the Department of the Air Force. The views expressed are those of the authors and do not reflect the official policy or position of the U. S. Government.

and receivers were included within the module for test purposes.

The most practical test method was to introduce IR radiation from inside the module. Heated panels, in the form of a central hexagon, were positioned in the area normally occupied by the FLTSAT apogee kick motor (AKM). Studies using a mathematical model of the test configuration indicated that boundary conditions sufficiently similar to flight conditions could be produced to test the performance of the system and verify the spacecraft thermal design.

TEST CONFIGURATION

The thermal-vacuum test facility is shown schematically in Fig. 2 with the module installed on the transporter. The vacuum chamber had a 2.4 m (8 ft) inside diameter and was 8.2 m (27 ft) long. The transporter rolled in for installation and the track, external to the tank, was removed. With the module installed, the North panel had approximately 18 cm (7 in.) clearance to the cold wall. The South panel opposite had more clearance because of the shape of the vacuum chamber.

The EHF module was thermally isolated from the transporter by supports incorporating fiberglass insulators and 10-W guard heaters. Some components of the antenna system and a vacuum gauge were also mounted on the transporter inside the module. The interface with the host spacecraft was not simulated. A top view of the setup is shown in Fig. 3.

The introduction of heat to the interior of the EHF module was accomplished using the smaller hexagonal structure mounted inside. This central hexagon was as tall as the module and 0.6 m (2 ft) on a side, roughly the size of the AKM. The faces were 0.16-cm (1/16 in.)-thick aluminum, painted flat black, and were thermally isolated from each other and the support structure. Each face was equipped with heaters and was separately controllable. This design was particularly appropriate because the central hexagon occupied the space normally occupied by the spacecraft motor and central support column.

The entire module was covered with multilayer-insulation blankets leaving only the mirror radiating apertures. The top and bottom openings, between the module and the central hexagon and within the central hexagon, were closed out. Blankets were also included inside the central hexagon, between the panels and their support frame.

MATHEMATICAL MODEL

A mathematical model of the flight configuration was developed for use with the Lincoln Laboratory Transient Thermal Analyzer, a network-analog, finite-differencing computer program. Model detail included box power dissipation and weight data, mirror and insulation-blanket definition on radiator panels, interfaces with the FLTSATCOM spacecraft module, aft-end solar heating, and orbital environments.

The flight mathematical model was revised to describe the test configuration. Only the parts of the EHF package included in the test were included in

the mathematical model. The solar arrays and attachments to the rest of the spacecraft were not included while the receiver front-ends and linear actuators were. The exterior node representing space was replaced with one representing the vacuum-chamber cold wall. Its temperature was increased to -180°C and its area was reduced to account for the proximity of the shroud. The cylindrical blanket surrounding the AKM was replaced by the central hexagon panels. These six nodes were given mass and input power. There was no sun loading.

A partial hexagon model was used for early verification of the computer analysis developed for the panels on the EHF module. A separate mathematical model was derived to provide predictions with which to compare results. Test detail and emphasis were concentrated on panels where high-power-density boxes were located. The North and South panels (panels 2 and 5), where thermal doublers were used, were tested separately. The outside face of the North panel contained film heaters beneath the silvered Teflon* tape used to simulate mirrors. These heaters produced boundary conditions consistent with solar heating on the North panel at end-of-life (EOL) summer solstice. The results of these tests correlated well with the mathematical model. Details of the math model derived for the test were incorporated into the flight model for use as a design tool and for flight predictions.

Boundary conditions for the flight system test could then be chosen to produce module temperatures similar to those expected in orbit. Initially power levels for the heated control panels were estimated by conducting a detailed accounting of average solar heating on panels and insulation, and comparing the results with the test configuration. Net heat losses through all insulation blankets facing the cold shroud were considered in the overall accounting, and the net power levels were adjusted to compensate for these losses. The power levels were then fine-tuned to produce temperature distributions which were similar to the various average steady-state conditions expected for flight.

TEST PROCEDURE

A dry-run thermal-vacuum test using an engineering model was conducted in February 1986. The engineering model is shown in Fig. 4 in the test configuration but without any blankets installed. Thermal-insulation blankets to be used in the test were first fitted to the engineering model and installed on the flight module after the dry run. The engineering model was instrumented and data were taken to test the control concept and verify a mathematical model of the test setup, particularly with respect to the central hexagon and the module's proximity to the cold wall. Three states resembling those of the flight system test were examined: simulated vacuum-bake, power-up, and beginning-of-life (BOL) equinox average.

The thermal-vacuum test of the flight EHF module was conducted in April 1986. Figure 5 shows the flight module in the test configuration. Functional tests were conducted under boundary conditions controlled with the central hexagon. Orbital average conditions of BOL equinox, EOL summer and winter

*Teflon: polytetrafluoroethylene resin manufactured by E. I. du Pont de Nemours & Co., Inc.

solstice, and BOL cold turn-on were simulated. The range of temperatures was roughly -20° to 50°C.

Preceding the start of testing, the vacuum chamber was pumped down without liquid nitrogen in the cold wall. The central hexagon was used at this time to heat one panel selectively in order to provide a preconditioning vacuum-bake environment. At the end of testing, during purge of the cold wall, heat from the central hexagon maintained module temperatures without power to the module. Under these conditions the flexibility of local control was beneficial.

Only steady-state equilibrium conditions were examined. Equilibrium was defined for the engineering-model test as no temperature change greater than 1°C in one hour. This was revised to 1°C in two hours for the flight-system test.

TEST RESULTS

Most of the temperatures measured in the engineering-model test were within 2°C of mathematical-model calculations. Details of the test setup, including the central hexagon and the vacuum-chamber cold wall, were modeled to sufficient accuracy.

In the flight EHF-module test, the majority of measured temperatures were within 5°C of predictions. Some of the highest and lowest power boxes exhibited the largest discrepancies, approaching 7°C, but in favorable directions. A high-power box was cooler than expected because of a lack of model detail defining the location of the highest power sections. Some low-power boxes were sensitive to ohmic heating of the wiring harness, which lined the perimeter of the structure, and were warmer than expected.

Panel-temperature distributions were close to those expected for average steady-state conditions in orbit. The Table lists some representative measured temperatures and mathematical-model estimates for the test arrangement. Corresponding estimates for average orbital conditions are also listed for comparison. No changes were made to the existing panel-insulation layout or mirror-aperture areas.

It is particularly noteworthy that temperature gradients produced at high-power-density boxes were similar to those expected in flight. One unit on the South panel dissipated almost 50 W. The temperature difference between the box sidewall and the panel mounting area was estimated to be 7°C for EOL winter conditions. A corresponding gradient of 8°C was produced in the EOL winter test. The internal IR heating technique did reproduce this type of temperature distribution.

CONCLUSIONS

In this configuration, the method of control worked as intended. The central hexagon supplied heat from inside the module to produce boundary conditions similar to those expected in flight. The technique provided flexibility for temperature control during various phases of vacuum-chamber operation. Internal IR radiation was a viable option for testing.

COMPARISON OF REPRESENTATIVE PREDICTED AND MEASURED
EHF MODULE TEMPERATURES

	<u>BOL Equinox Average Temperature (°C)</u>		
	Test Mathematical Model Prediction	Test Measurement	Flight Mathematical Model Prediction
Panel 1 Component Panel	23 19	22 17	23 18
Panel 2 Component Panel	22 13	18 10	21 15
Panel 3 Component Panel	12 8	11 --	13 8
Panel 4 Component Panel	23 14	21 18	19 12
Panel 5 Component Panel	34 27	33 24	30 24
Panel 6 Component Panel	19 16	17 17	17 14

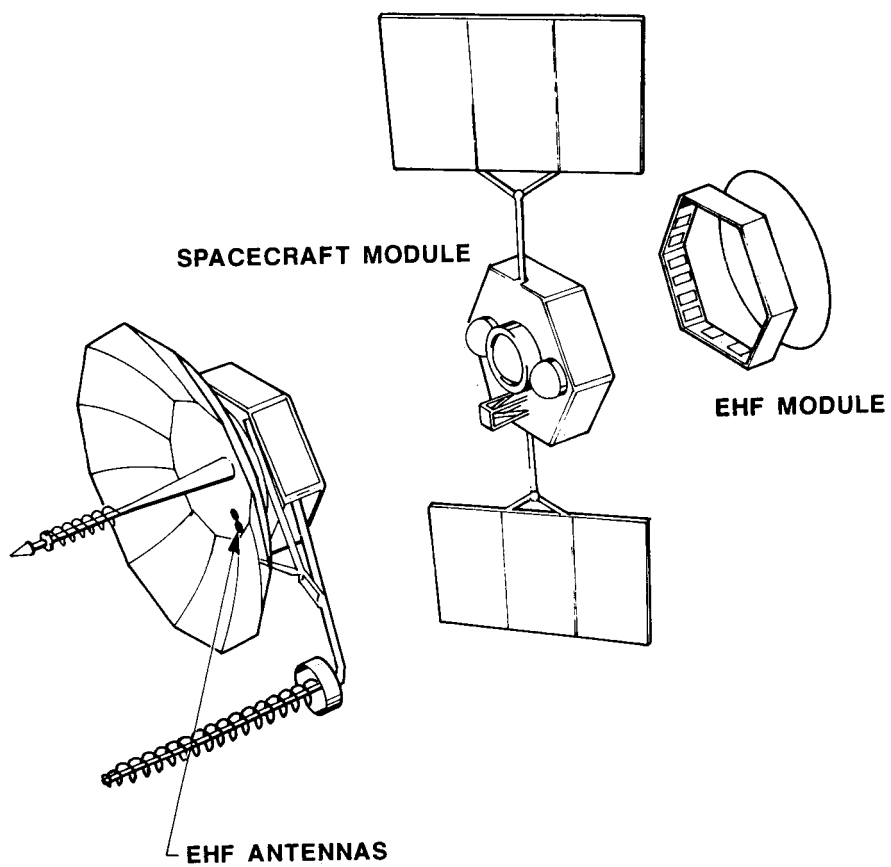


Figure 1. FEP arrangement

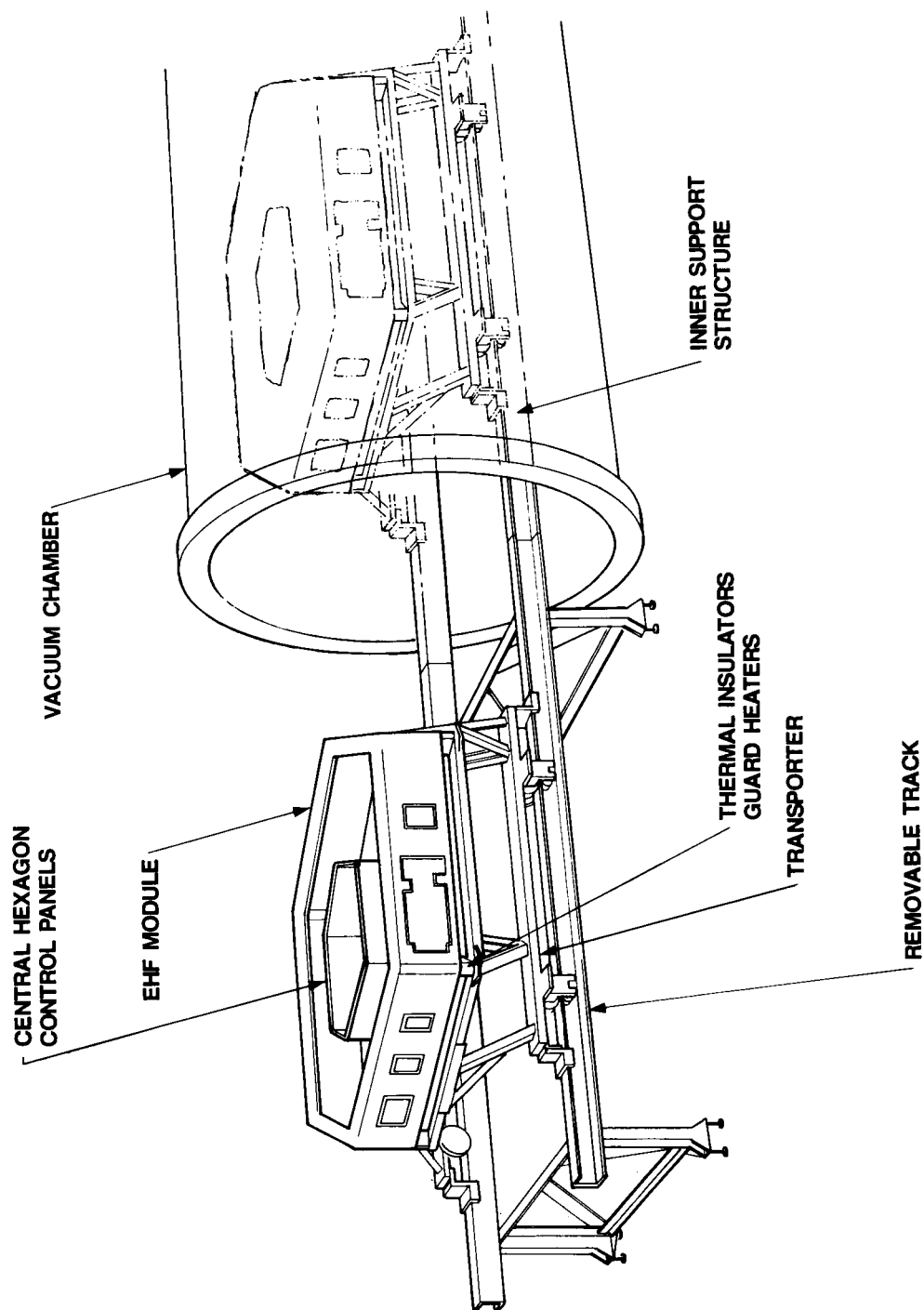


Figure 2. EHF module thermal-vacuum test configuration

ORIGINAL PAGE IS
OF POOR QUALITY

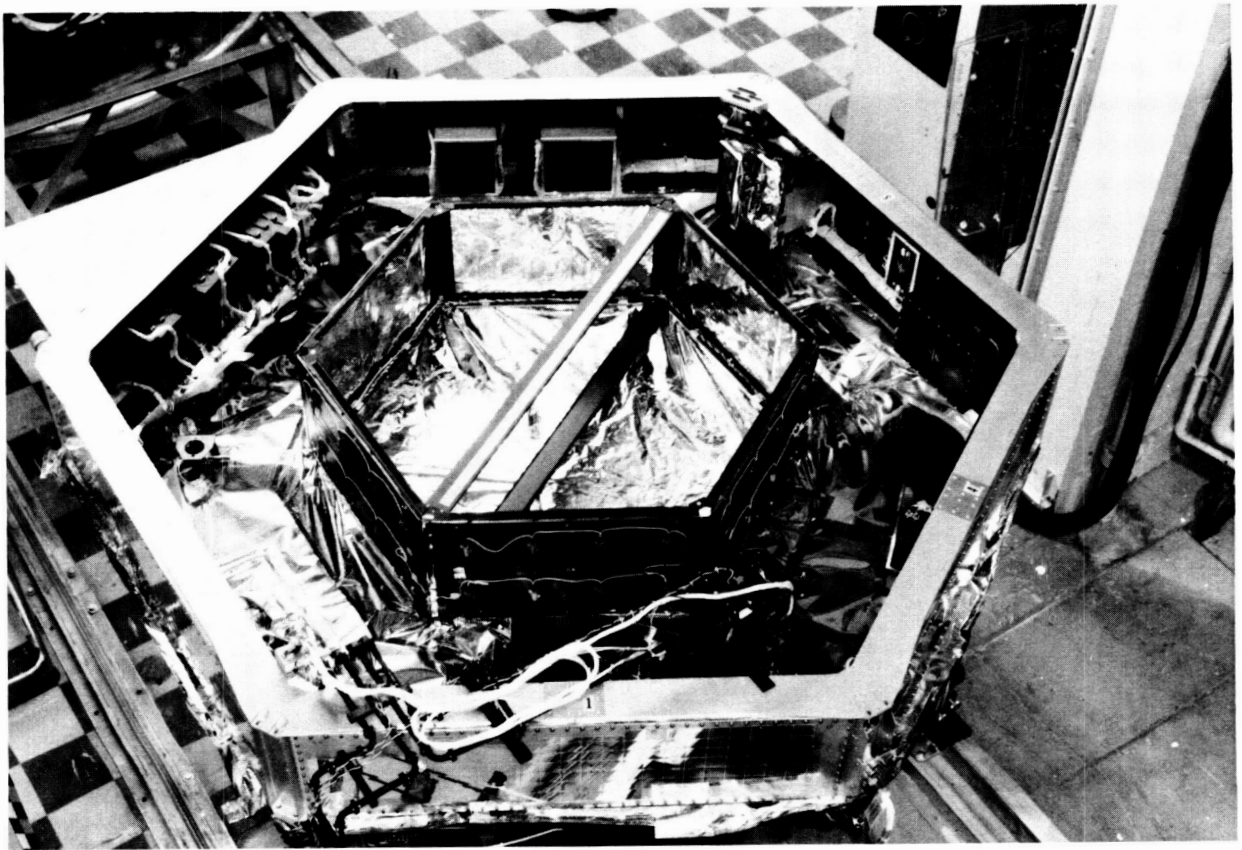


Figure 3. EHF module and central hexagon, top and panel blankets removed

ORIGINAL PAGE IS
OF POOR QUALITY

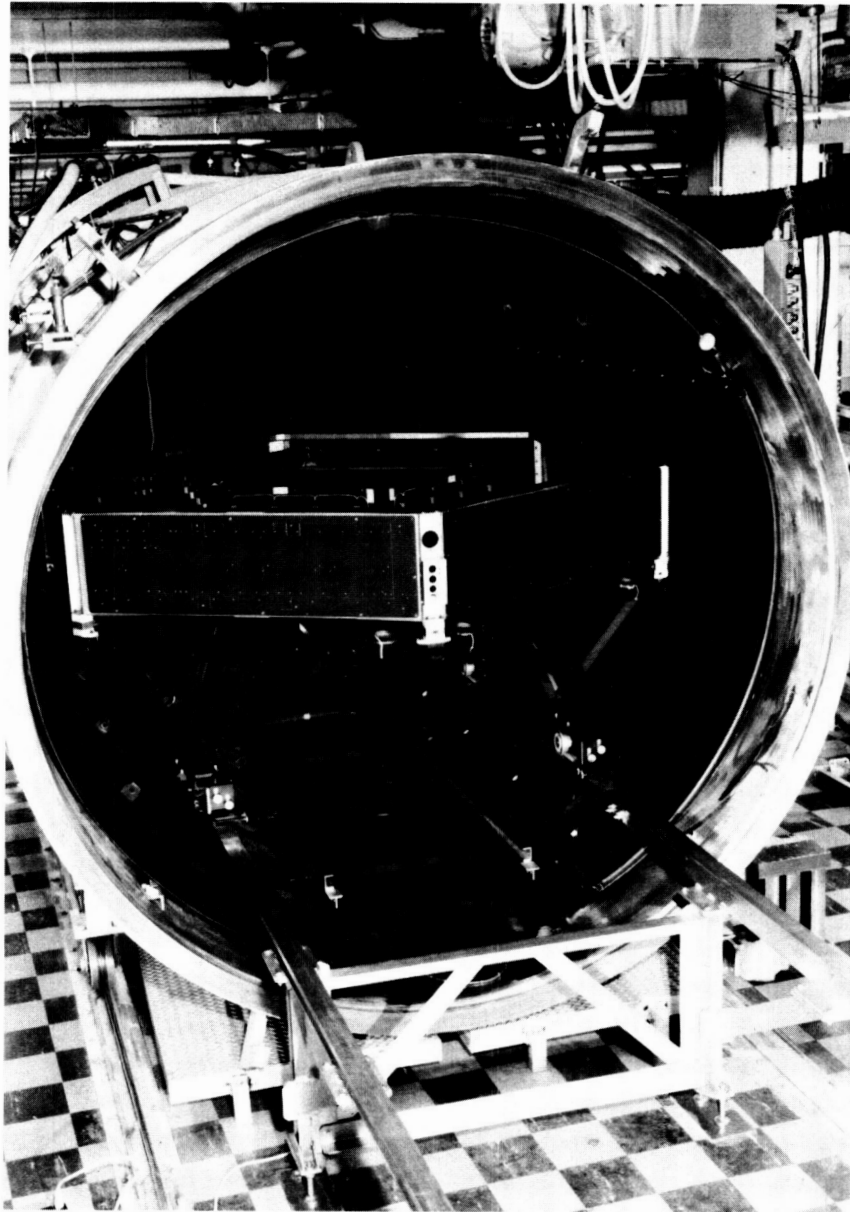


Figure 4. Engineering model in thermal-vacuum test configuration without insulation blankets.

ORIGINAL PAGE IS
OF POOR QUALITY

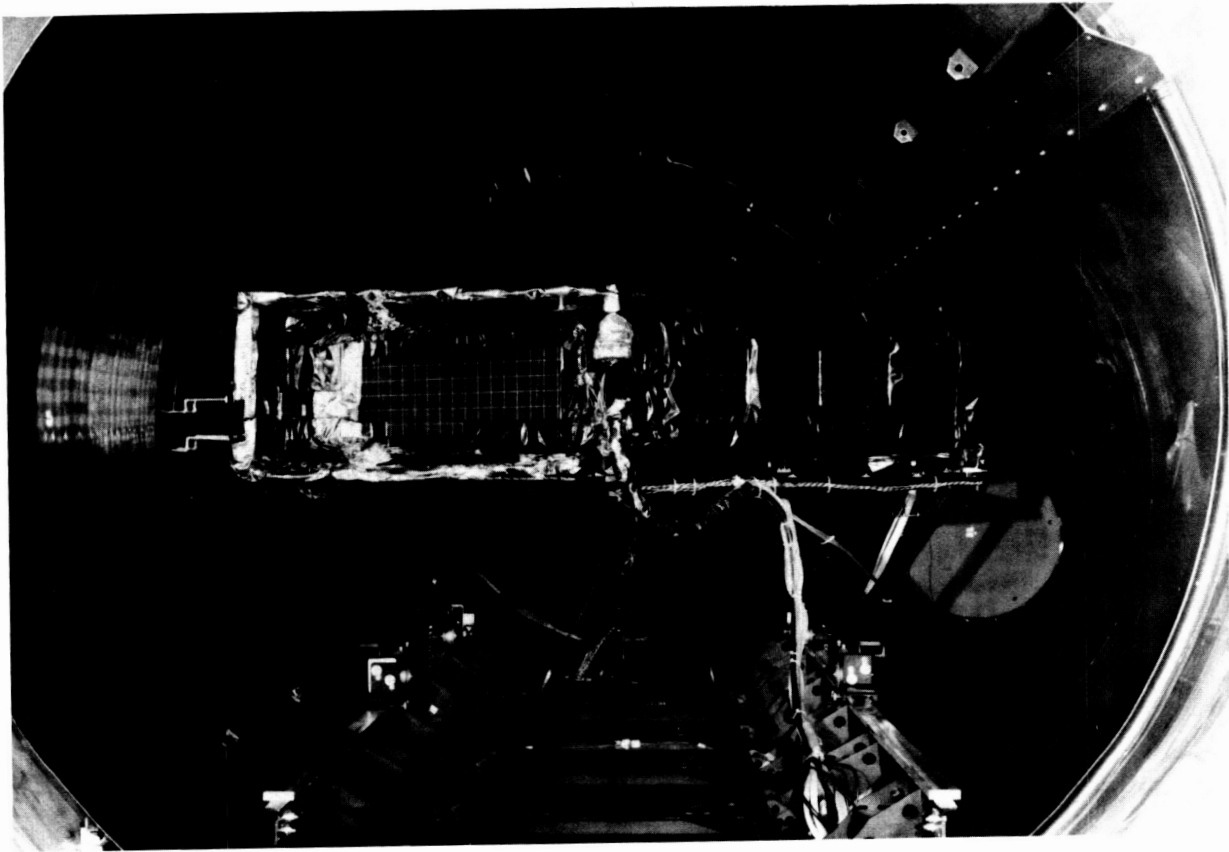


Figure 5. EHF module in thermal-vacuum test